MEGAN Biogenic Emissions in WRF-Chem

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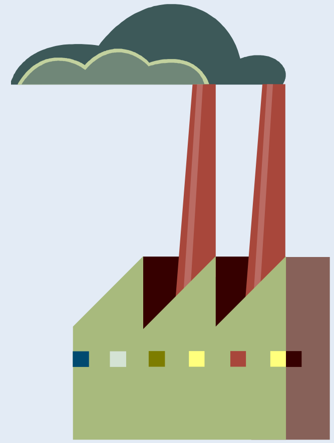
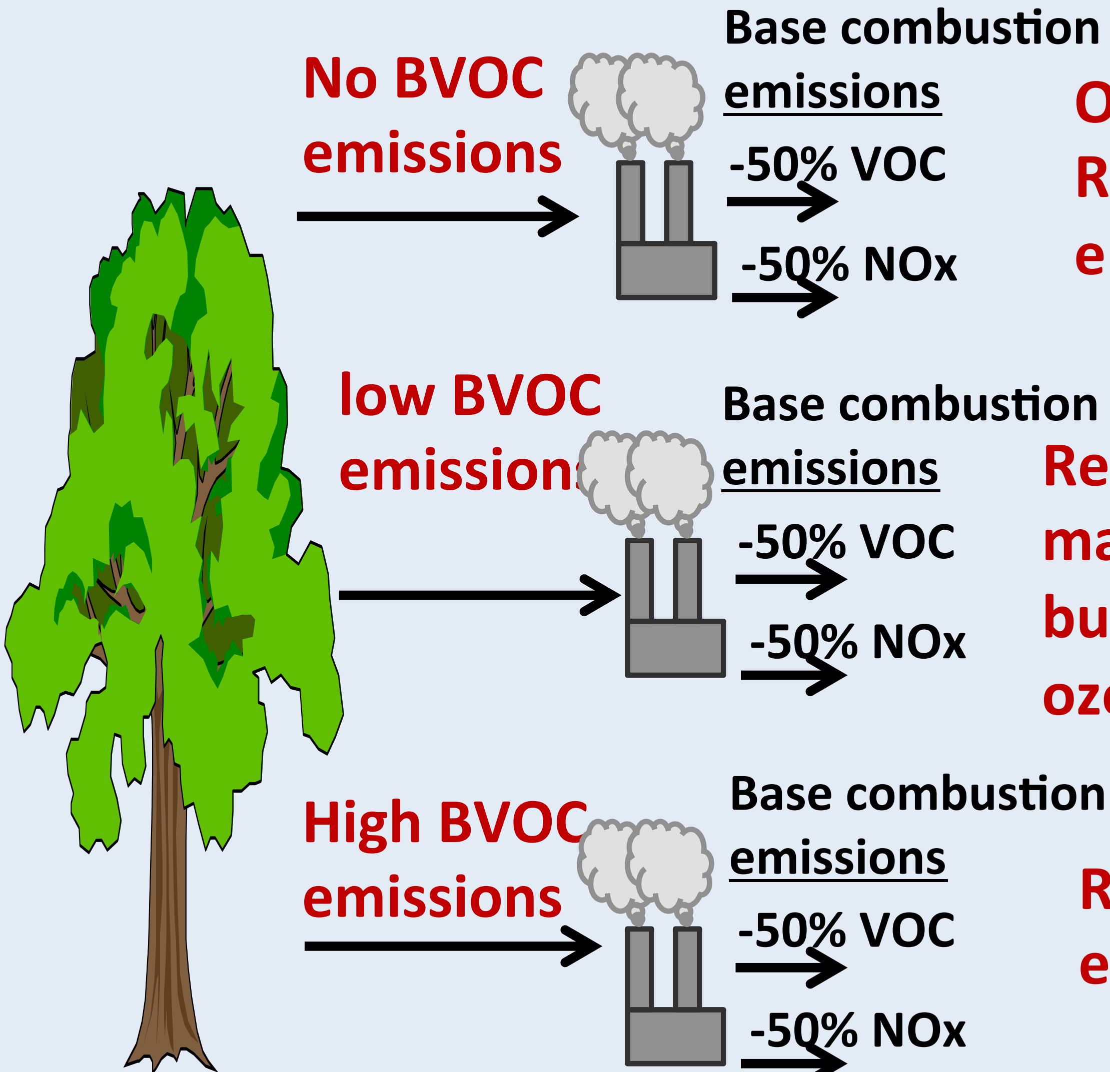
Emissions for Chemical Transport Models

- Point
- Area
- Mobile
  - On-road
  - Off-road
- Biogenic
- Fire



Biogenic VOC have an role in ozone production

1980s: Controversial 1990s: Widely accepted



Ozone control strategy: Reduce fossil fuel VOC emissions

Reducing VOC better for maximum ozone (> 120 ppb) but reducing NOx better for ozone in most of the domain

Reduce fossil fuel NO_x emissions

RADM Eastern U.S. air quality model simulations

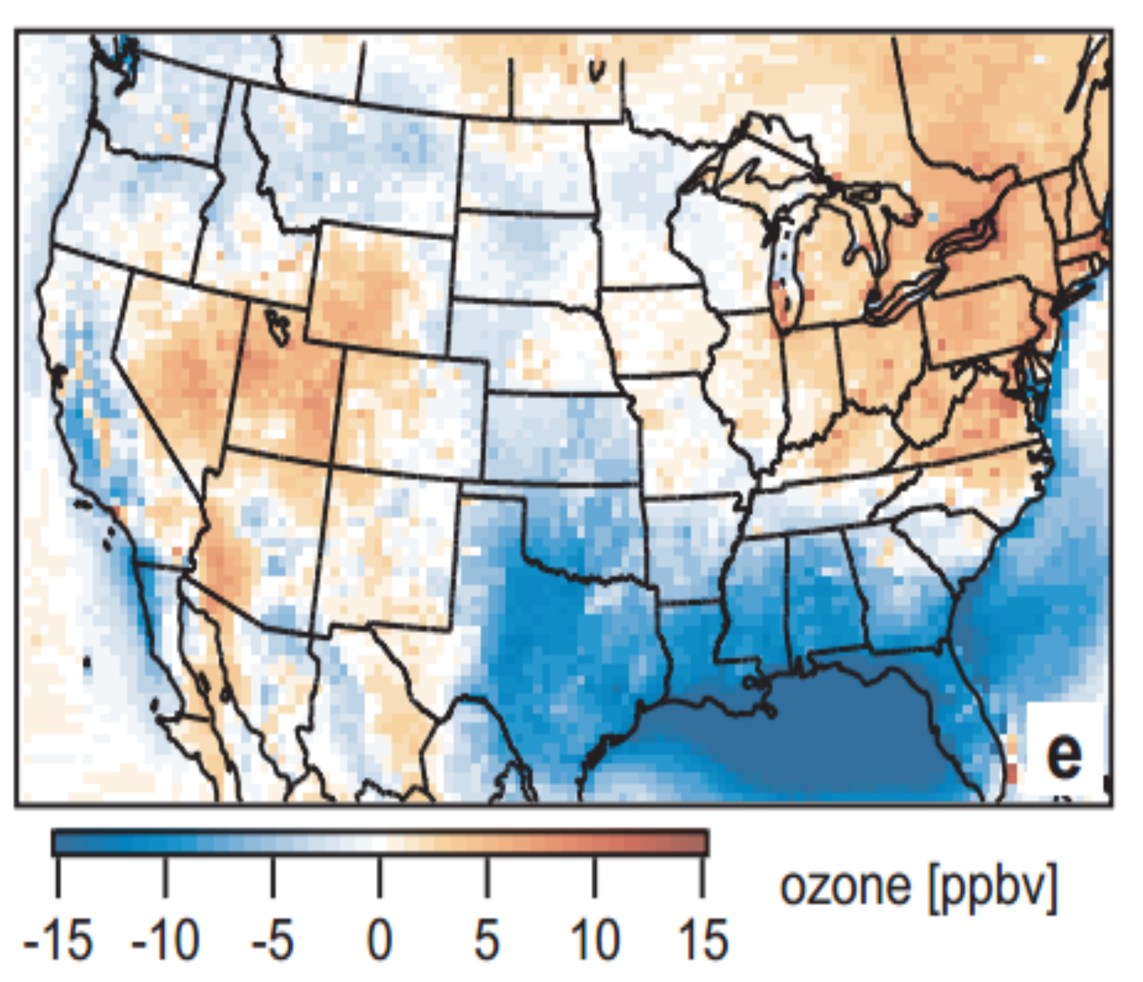
Pierce et al, JGR 1998

BVOCs have a role in the "Climate penalty on air quality": Higher temperatures will increase ozone

The relationship between temperature, BVOC and ozone is complex:

Ozone increases due to temperature-driven increased VOC emissions and decreased cloud cover.

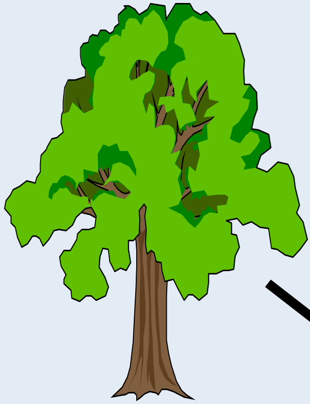
Ozone decreases due to higher boundary layer and increased clouds and precipitation



Avise et al. 2009
CMAQ/MEGAN model

2040s – 1990s daily maximum 8hr ozone

BVOC role in the "Air quality penalty on climate": Better air quality (fewer particles) warms climate (less cooling)



BVOC

Some SOA formed in clean environment

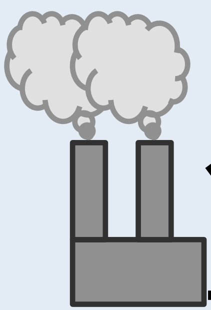
"Uncontrollable" SOA: Natural organic aerosol

Carbon from BVOC is processed by anthro. pollution: seed aerosol, oxidants, high NOx, SO2

Controllable biogenic SOA

"controlled" by air quality control strategies

This is NOT natural aerosol!



VOC, NOx, SO2, particles

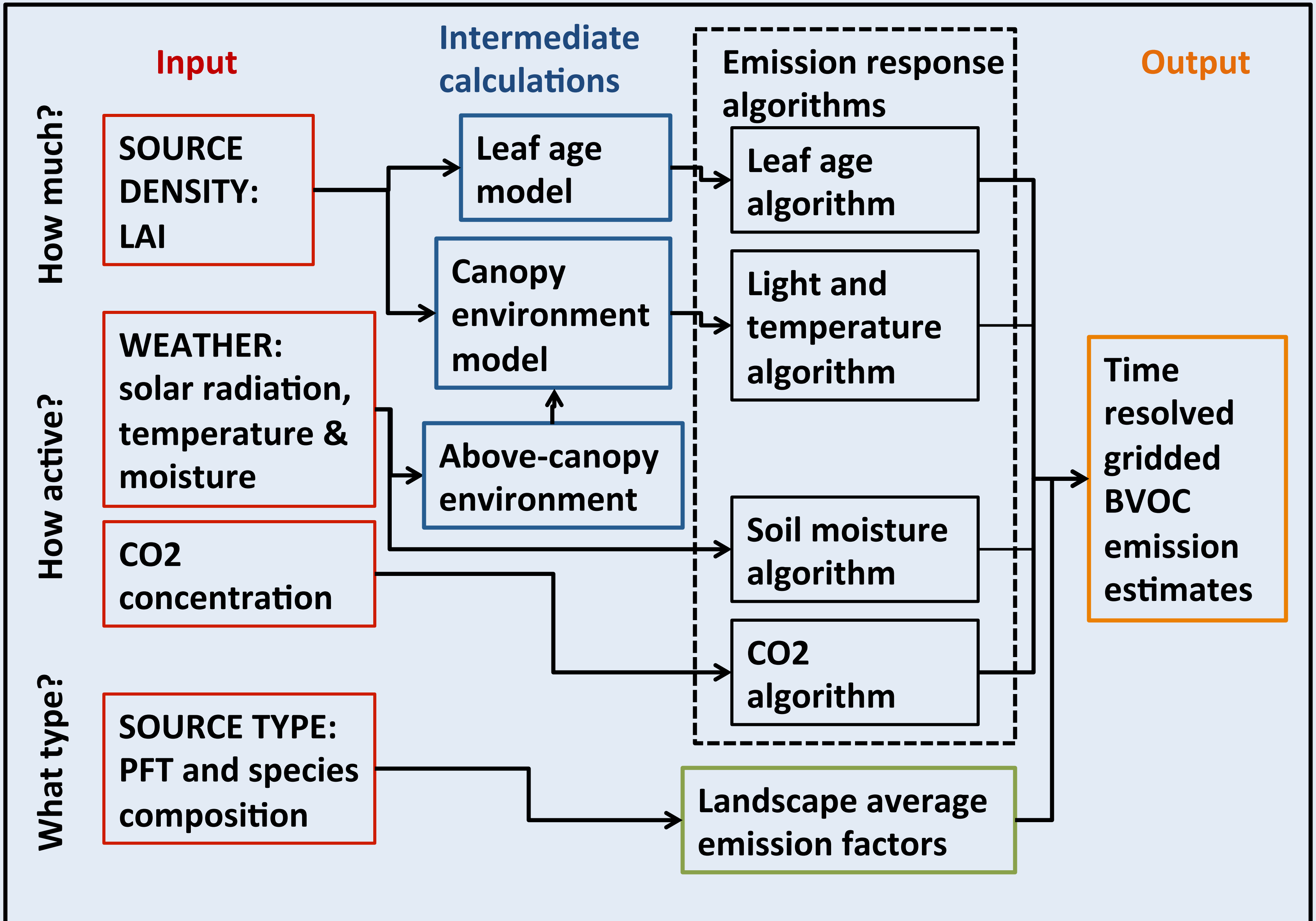
Some SOA from anthro. VOC

Controllable SOA

Carlton et al. 2010, Hoyle et al. 2011, Spracklen et al. 2011

Setyan et al. 2012, Shilling et al. 2013

We have incorporated our quantitative understanding of BVOC emissions into numerical models: Model of Emissions of Gases and Aerosols from Nature (MEGAN)

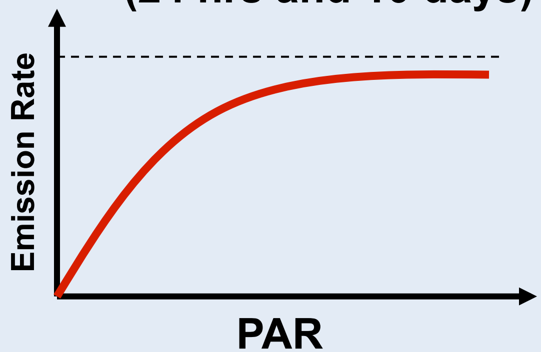


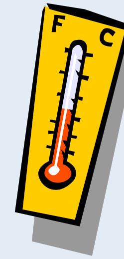
Guenther et al. (2006, 2012)

We have reasonable quantitative descriptions of BVOC emission responses for most of the key drivers

LIGHT

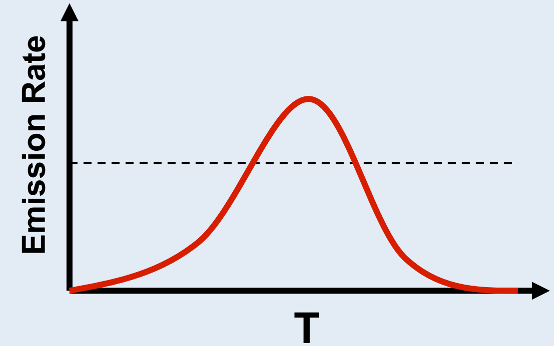
Diffuse and direct radiation
Instantaneous and accumulated
(24 hrs and 10 days)

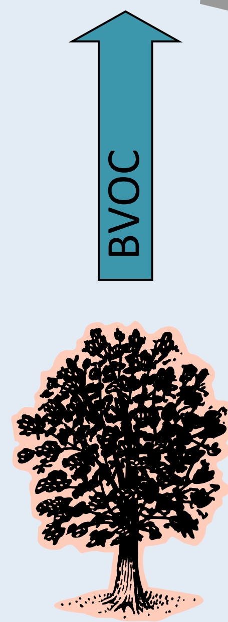


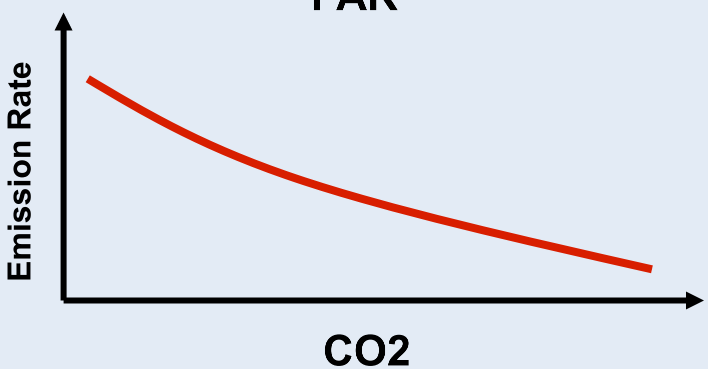


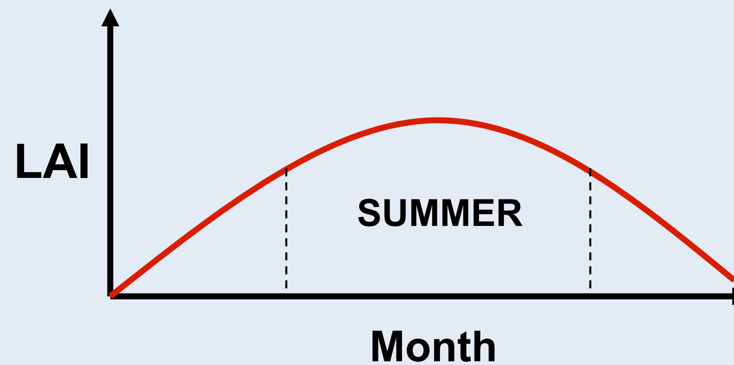
TEMPERATURE (Leaf-level)

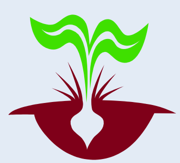
instantaneous and accumulated
(24 hrs, 10 days)







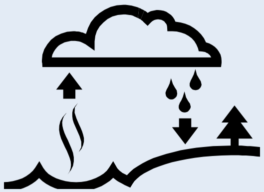




LEAF AGE

Mature: High Iso., Low MeOH
New: Zero Iso, High MeOH

and are working on others

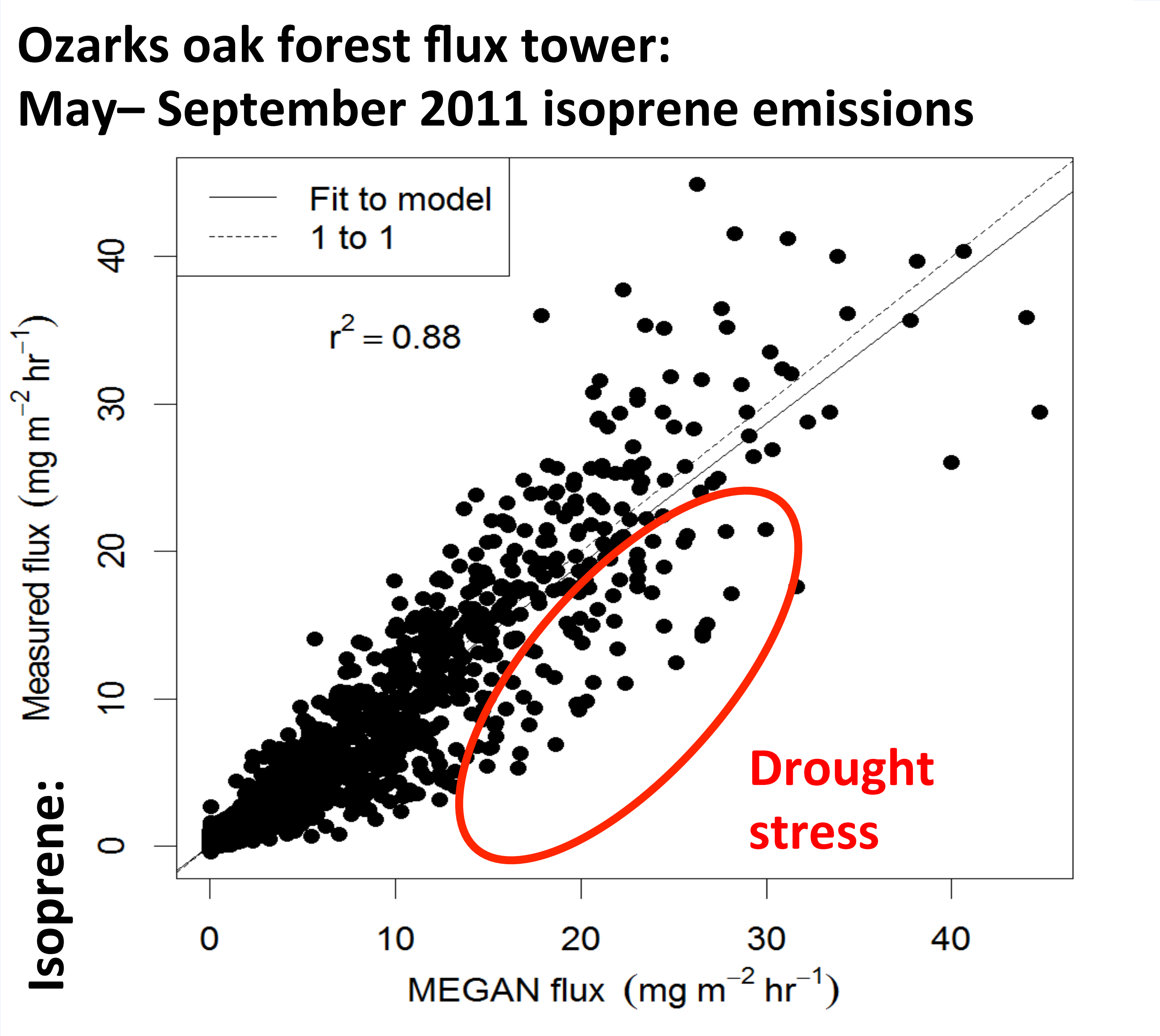


SOIL MOISTURE

HERBIVORY & other stresses

We have preliminary algorithms for some stresses:
e.g., drought and storms (hail, winds)

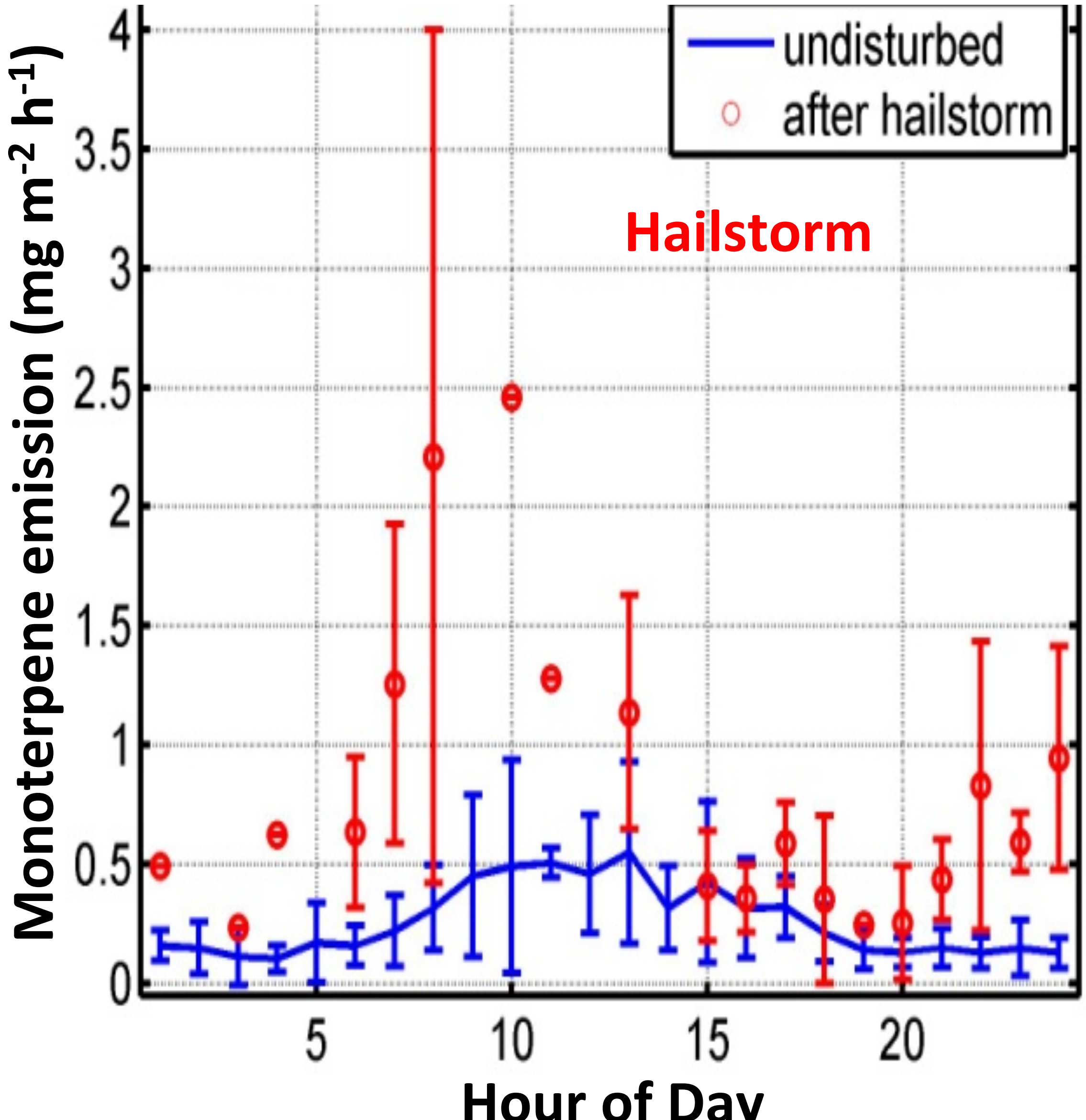
MEGAN can account for most (88%) of the observed variations in isoprene fluxes



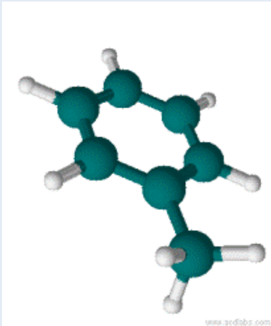
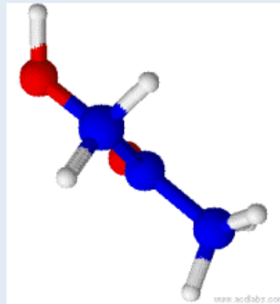
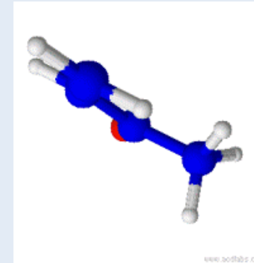
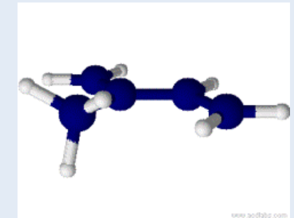
Potosnak et al., in prep

We are working on algorithms to quantify BVOC response to stress

Colorado pine forest flux tower: August 2011 monoterpene emissions



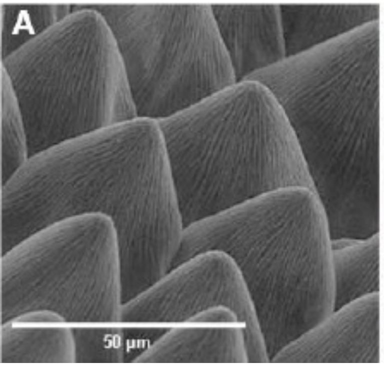
Kaser et al., in review

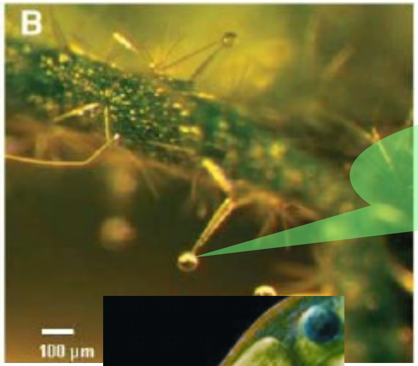





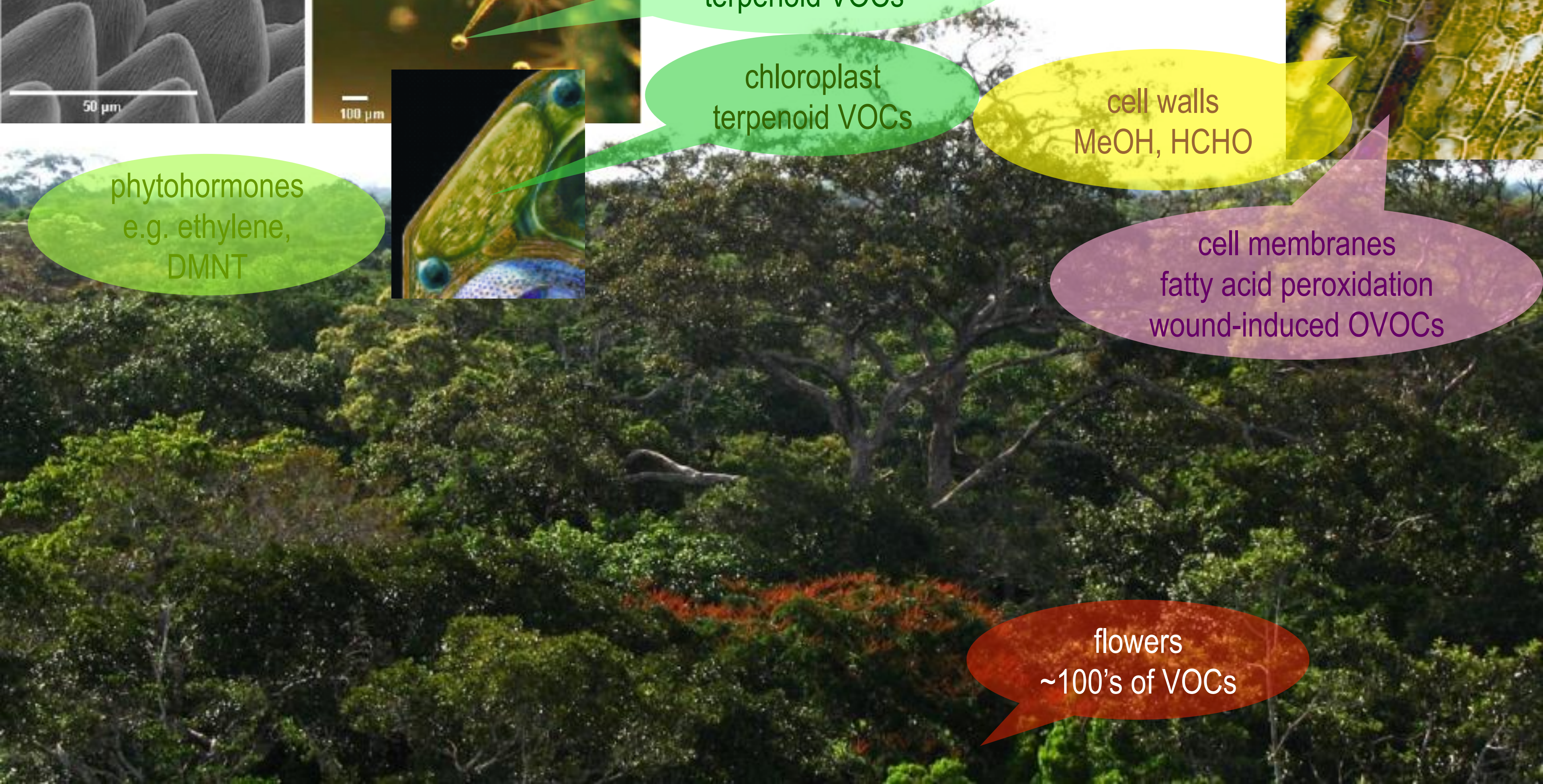
A major challenge is associated with representing the immense chemical and biological diversity of BVOC “emission factors”.



There are hundreds of BVOCs emitted from Vegetation

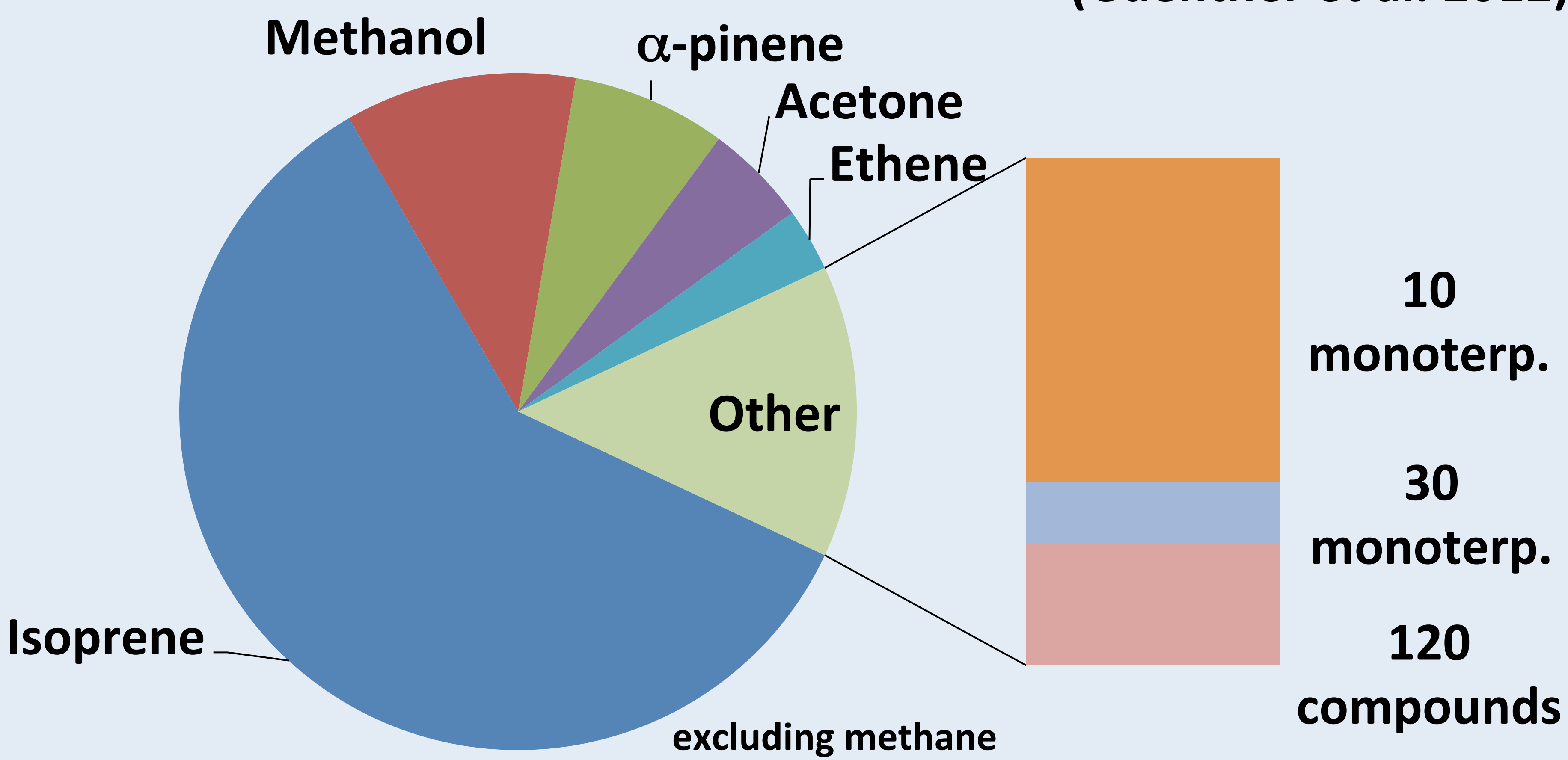






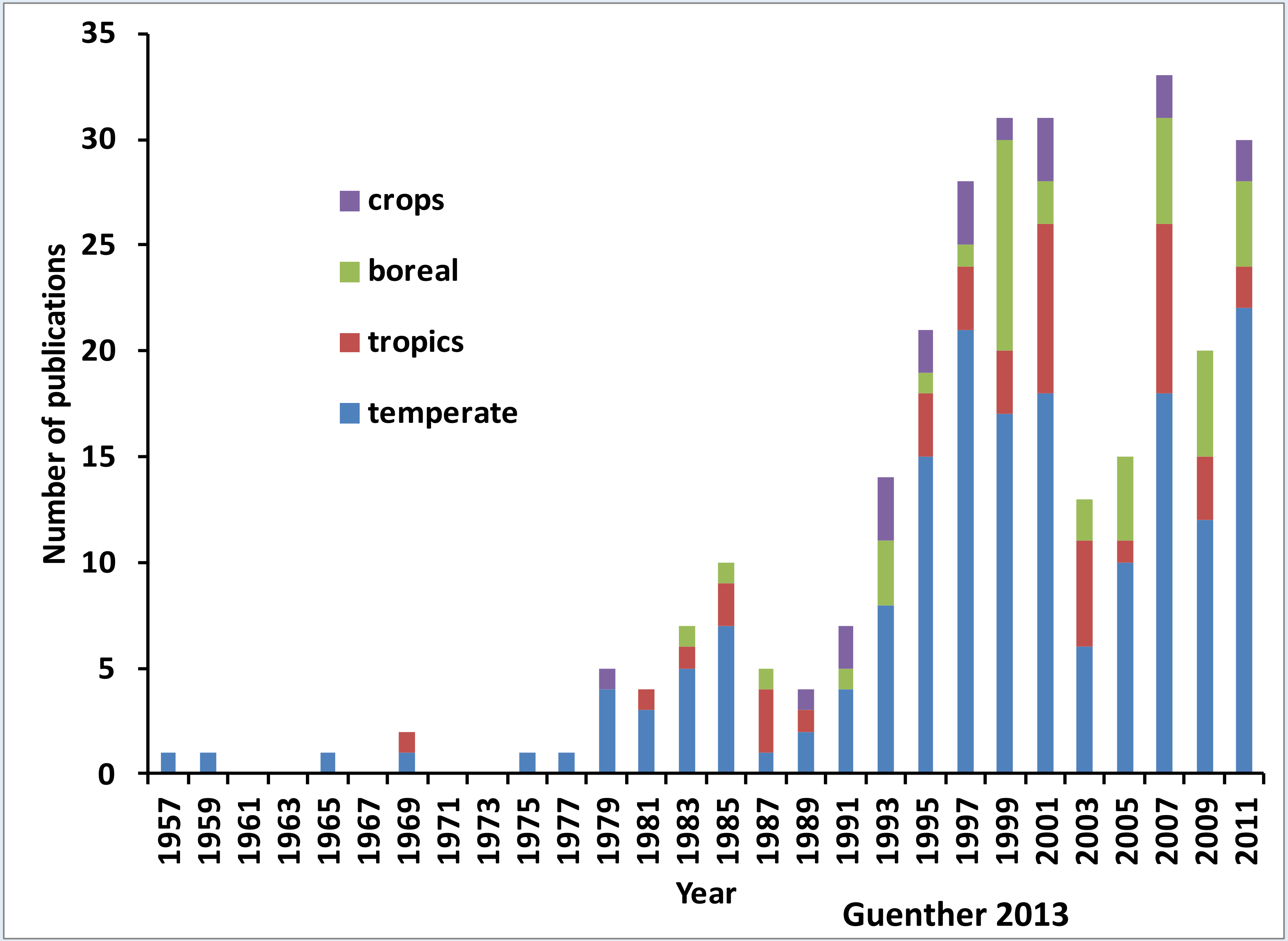
There are hundreds of BVOC emitted into the atmosphere but relatively few compounds dominate the total

(Guenther et al. 2012)

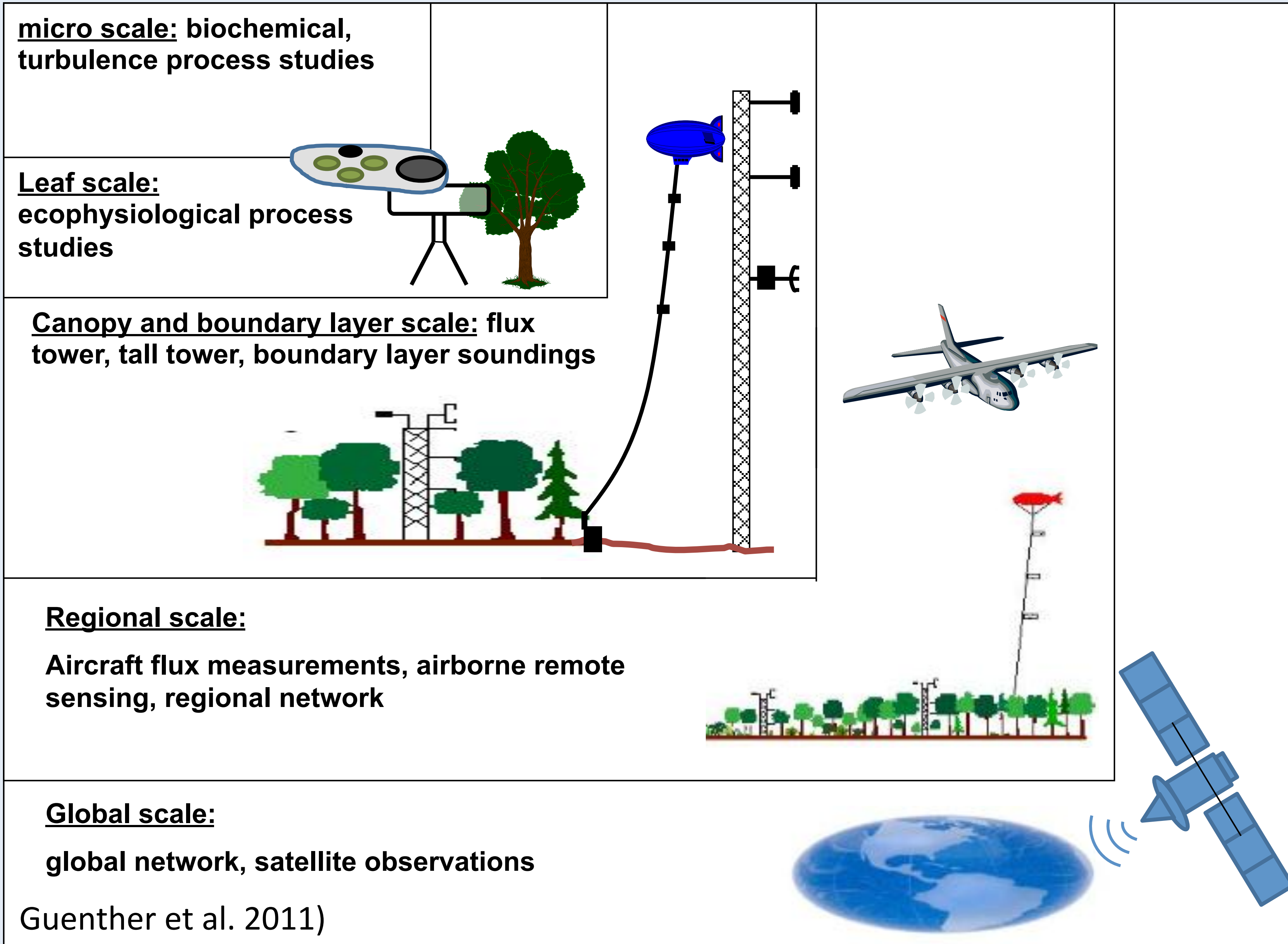


but some minor compounds may make important contributions to SOA and can even dominate total BVOC emissions at a particular location and time

The MEGANv2.1 model is based on observations from > 300 studies



Across a range of scales …



Model approaches to account for BVOC emission chemical diversity

USEPA BEIS (1991)
2 compounds, 4 types
Isoprene, a-pinene, other monoterpenes, and unidentified

GEIA (Guenther et al. 1995)
1 compound, 4 types
Isoprene, monoterpenes (e.g., a-pinene), other reactive VOC (e.g., MBO), other VOC (e.g., methanol)

MEGAN2
(Guenther et al. 2006)
139 compounds
20 types

MEGAN2.1
(Guenther et al. 2012)
147 compounds
18 types

MEGAN 3.0:
~200 compounds
~9 types

Biological diversity: BVOC emission magnitude and composition varies greatly among plants

Loblolly pine: Moderate emissions dominated by pinenes

Mushroom: low emissions dominated by octanol

Red Oak: High emissions dominated by isoprene

Tulip tree: low emissions dominated by methanol

Ponderosa pine: High emissions dominated by MBO

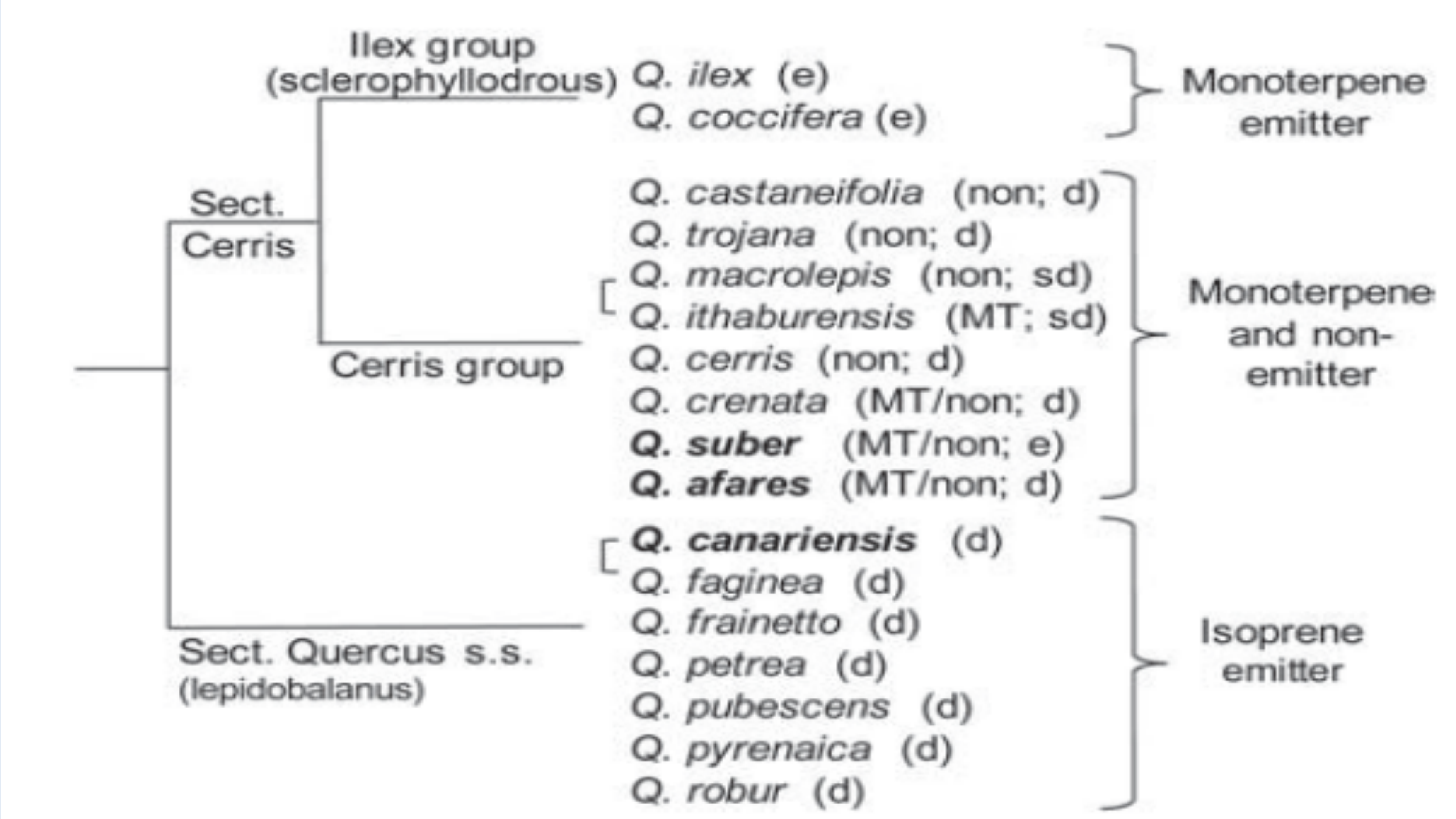
Sugar maple: moderate emissions dominated by sabinene

Biological BVOC emission diversity

MEGAN 2.0 (Guenther et al. 2006)
isoprene emission factors (mg m^{-2} h^{-1})

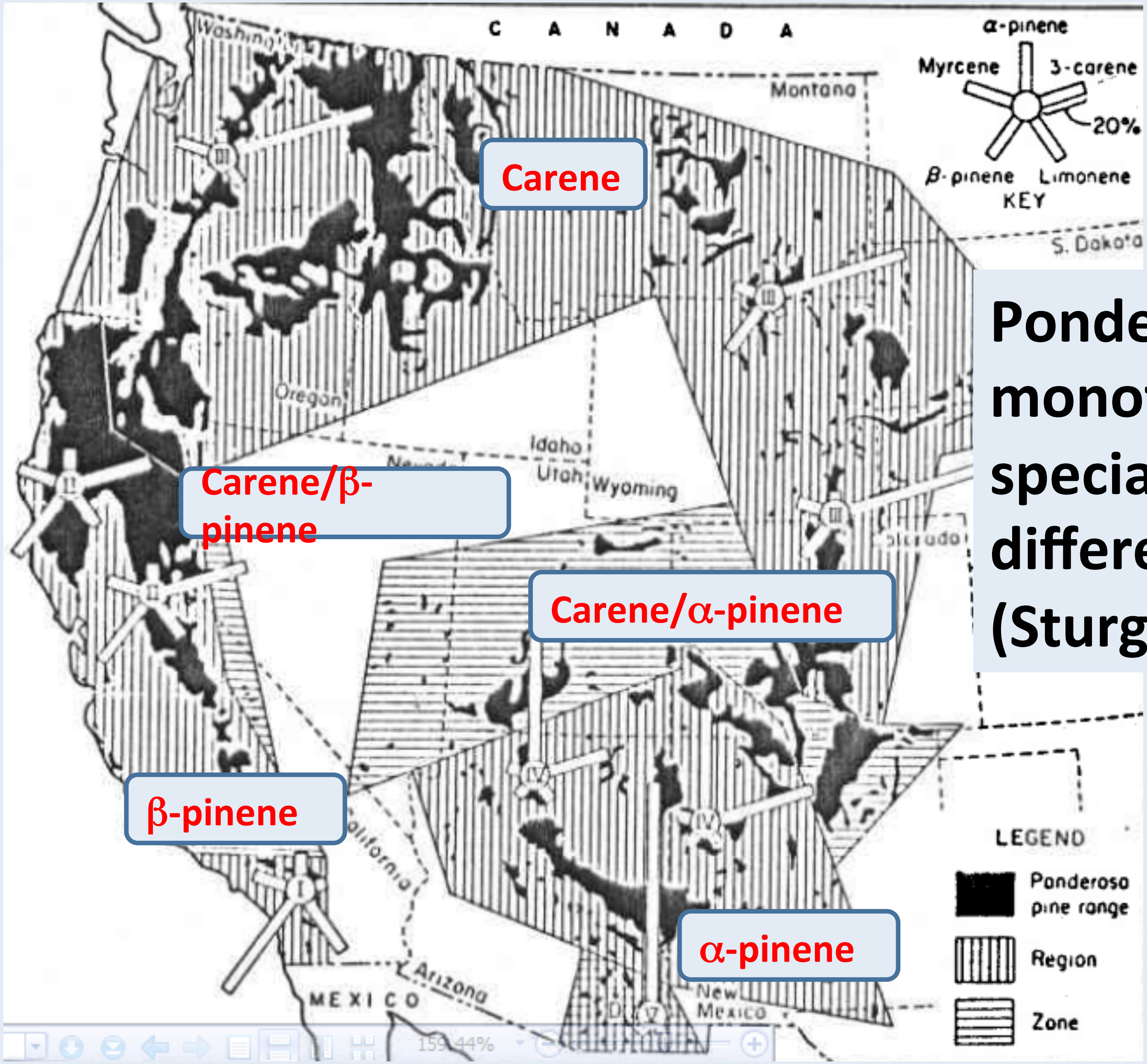
Major plant types	Mean	Range
Broadleaf trees	12.6	(0.1 – 30)
Shrubs	10.7	(0.1 – 30)
Needle evergreen trees	2.0	(0.01 – 30)
Narrowleaf decid. trees	0.7	(0.01 – 2)
Herbaceous	0.5	(0.004 – 1.2)
Crops	0.09	(0.01 – 1)

Species level BVOC emission diversity: The oaks



Q. afares **is a stabilized hybrid of** ***Q. suber*** **and** ***Q. canariensis*****. It does not emit isoprene and has highly variable monoterpene emission (Welter et al. 2012)**

BVOC diversity within a species: The pines



Ponderosa pine tree monoterpene resin speciation varies for different U.S. regions (Sturgeon 1979)

How many isoprene emission types do we need to describe North American broadleaf trees?

North American Broadleaf Trees # of emission classes	L87 2	G94 4	B97 14	G01 2?
Acer rubrum	0	0.01	0	0.01
Quercus agrifolia	13.6	70	31.1	77
Q. chrysolepis	13.6	70	21.9	48
Q. douglasii	13.6	70	7.7	71
Q. engelmannii	13.6	70	21.9	39
Q. lobata	13.6	70	3	86
Q. kellogii	13.6	70	21.9	78
Q. wislizenii	13.6	70	1	74
Liquidambar styraciflua	13.6	70	16.7	68
Nyssa sylvatica	13.6	14	--	77
Platanus occidentalis	13.6	35	24.3	71
Robinia pseudoacacia	13.6	14	10.5	151
Salix nigra	13.6	35	22.2	93
Populus deltoides	13.6	70	37	97

Isoprene emission factors ($\mu g\ g^{-1}\ h^{-1}$) at leaf temperature of 30°C and PAR of 1000 $\mu mol\ m^{-1}\ s^{-1}$

Emission factors based on enclosure measurements

L87: Lamb et al. 1987

G94: Guenther et al. 1994

B97: Benjamin et al. 1997

G01: Geron et al. 2001

These data suggest we may only need two categories of North American Broadleaf trees: non-emitters and emitters

Model approaches to account for BVOC emission biological diversity

USEPA BEIS (1991)
17 land-use types:
3 forest, 11 crop, range, urban, barren

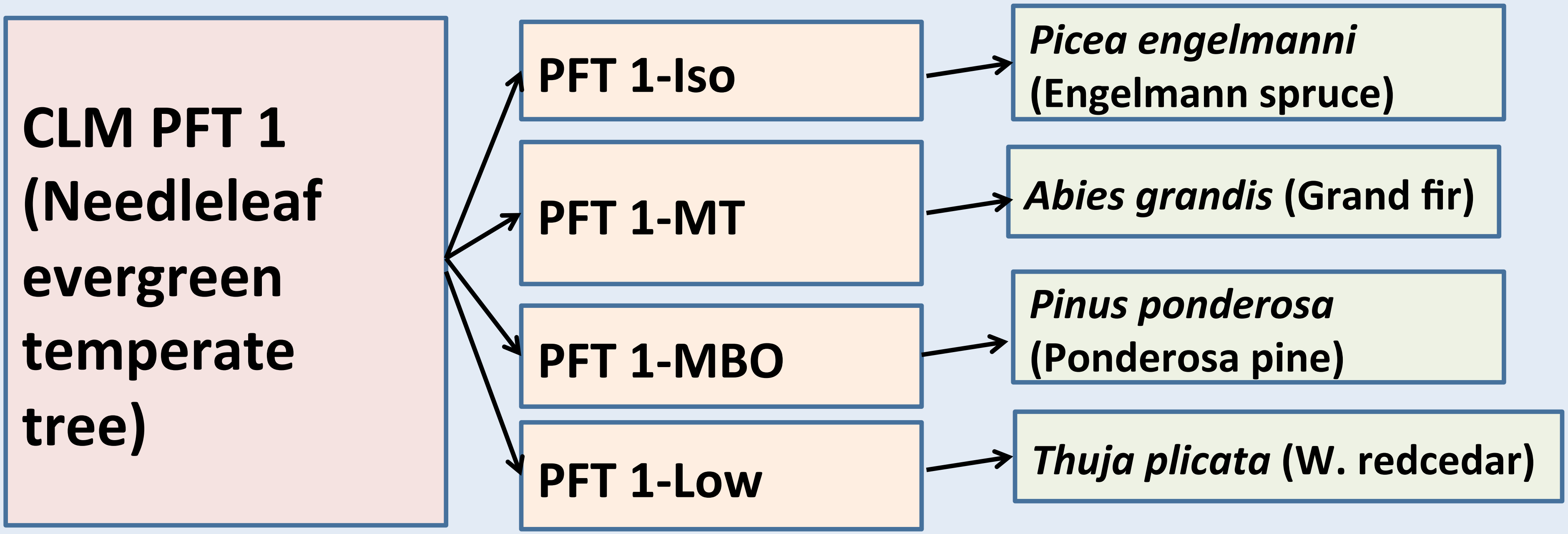
GEIA (Guenther et al. 1995)
57 global ecoregion types: including monoculture (e.g., paddy rice, mangrove) and mixed (cool farm/city, dry deciduous, mixed forest)

MEGAN2 (Guenther et al. 2006)
5 Plant Functional Types (PFTs)

MEGAN2.1 (Guenther et al. 2012)
15 CLM Plant Functional Types (PFTs)

MEGAN 3.0: ~40 PFTs

MEGAN 3.0 approach to account for BVOC emission biological diversity



Define a "type" species.

Add more PFTs if demonstrate another type that

1) **has a significantly different emission spectra**
2) **is an important component of a region**

What is available for WRF-Chem?

- Currently available: MEGAN 2
- Almost ready for release to the WRF-Chem community: MEGAN 2.1 integrated into the Community Land Model (CLM).
- Under development: MEGAN3, which will also be integrated into CLM

Thank-you for listening

Any Questions?

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